

Surges of Maritime Tropical Air Northward Over the Gulf of California

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ABSTRACT—Several surges of maritime tropical air into the deserts of Arizona and California are investigated. These surges are related to the large cloud masses of tropical origin located over the Gulf of California. A natural channel exists for this surge transport; it is about 200 mi in width, the western boundary being the rugged

ridge line extending the length of Baja California and the eastern boundary being the broad Sierra Madre Range. The surge process resembles that of a very large-scale sea breeze with the greatest energy transport occurring near the surface and disappearing in the middle troposphere. Four case studies are analyzed in detail.

1. INTRODUCTION

The Gulf of California has been generally ignored as a possible weather influencing region. This paper will describe conditions in which the gulf has a synoptic scale influence, possibly unlike that of any other location on the globe.

Due to terrain boundaries both east and west of the Gulf of California, a natural channel about 200 mi wide exists from the tropical Pacific into the deserts of southwestern United States. During summer, the air mass varies from a very warm, dry, continental type near the northern end to a cooler, moist, tropical type at the mouth of the gulf (Environmental Science Services Administration 1966, Green and Sellers 1964, Green 1963). Under normal conditions, a thermal-dynamic balance exists between the air mass over the Gulf of California and Arizona, and that over the tropical Pacific Ocean west of central Mexico. This would imply no large fluxes of moisture inland from the gulf, only very low-level moisture spreading inland several miles mostly under a land-sea breeze regime unless something occurs to upset this equilibrium.

A possible mechanism for upsetting this equilibrium is suggested after 2 yr of observing and studying satellite cloud photographs and surges of tropical maritime air into the desert Southwest. A relationship has been noted between the arrival of large cloud masses over the central or extreme southern portions of the Gulf of California and the subsequent occurrence of northward surges of moisture into Arizona.

A possible explanation of this relationship is that the passage of a tropical disturbance or large cloud mass across the mouth of the gulf could effectively increase the slope of the tropical air mass boundary to the extent that it becomes unstable and moves up the progressively hotter gulf toward the heat Low in the desert Southwest. A dome of higher pressure under clouds associated with convective activity, evaporational cooling from precipitation, and differential heating in and outside the cloud

area could have the same effect. These surges bring significantly cooler and more moist air into the deserts of Arizona and parts of southern California and to a lesser extent into Arizona's mountains. The moisture increase can result in heavy convective rainfall or, when combined with a middle-latitude disturbance, a flood-producing storm such as the one that occurred on Sept. 5, 1970 (Zimmerman et al. 1971).

In the following two sections, the apparent mechanisms and characteristics of the "gulf surge" are described, and in section 4, case studies of four surges are presented.

2. MECHANICS OF THE GULF SURGE

The most important aspect of the Gulf of California as related to Arizona weather is that it is an open channel from the tropical Pacific to the desert Southwest. Yuma, Ariz., near the northern end of the gulf, is at 33°N while the mouth of the gulf is at 23°N. As can be seen in figure 1, the mountain ridge line along the Baja California Peninsula from 26°N northward averages well above 2,000 ft in elevation with only a few east-west breaks. South of 25°N the ridge line has an average elevation of less than 2,000 ft with only a few peaks above 4,000 ft.

Because of the channeling effect over the gulf, particularly north of 25°–26°N, any northward surge of tropical Pacific air would be confined to an area bounded on the west by the higher terrain over Baja California and on the east by the foothills of the Sierra Madre, which begin between 50 and 100 mi inland from the west coast of Mexico. This terrain provides a natural channel rather uniformly about 200 mi across. Also, because frictional resistance to air movement is much less over water than over land, the strongest portion of a surge would remain over and just adjacent to the gulf itself where nearly laminar flow would prevail. The width of the gulf is 60–100 mi.

During July, August, and usually part of September, Arizona and northwestern Mexico are dominated by a very warm, relatively dry air mass, particularly in the



FIGURE 1.—Topographic map of northwestern Mexico and southwestern United States illustrating the natural channel from the Pacific Ocean to Arizona.

lower levels of the atmosphere. Below 10,000 ft, this air mass contrasts rather markedly with the tropical Pacific air mass overlying the ocean west of Mexico south of 24°N. Average temperature and dew-point soundings for the month of August 1969 for Tucson, Ariz. (representing the interior regions), and for Mazatlán, Mexico (representing the tropical ocean area), are shown in figure 2. Temperature differences in the intermediate levels of the troposphere above the 700-mb level are negligible, but below 10,000 ft the air mass overlying the tropical Pacific west of Mexico is much cooler with considerably higher relative humidities than the air mass over the deserts of the southwestern United States.

Thus, there is almost always, in the hotter months, a potential for a flux of air northward from the Pacific. Normally, a balance exists between these differing air masses and no northward flux occurs. However, any mechanism that accentuates this normal thermal and pressure differential will upset the equilibrium state and initiate a surge up the gulf. Whenever a cloud mass, possibly associated with a tropical disturbance, of significant size and thickness (at least 2° of latitude by 2° of longitude and composed of convective and middle-type cloudiness) either crosses the Gulf of California or moves into the mouth of the gulf, a northward surge of moist tropical air is generated. In addition, temperatures in the western deserts of Arizona as well as in Sonora, Mexico, must be seasonably hot with steep lapse rates. This

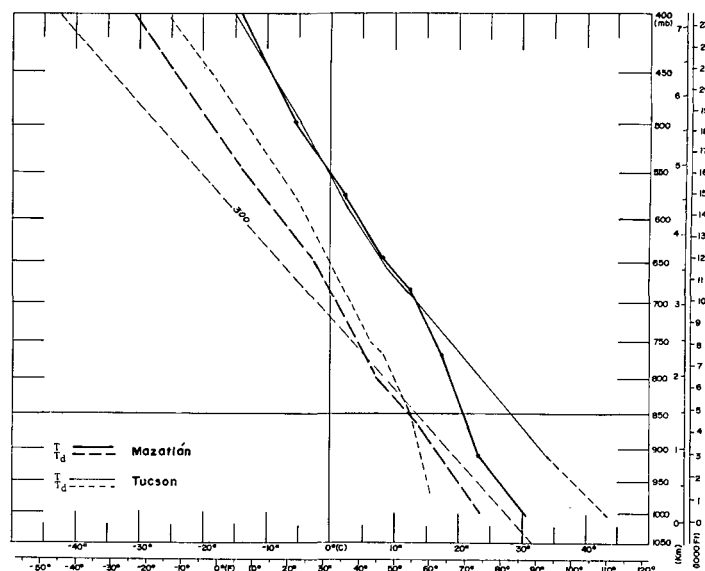


FIGURE 2.—Average August 1969 dew-point and temperature soundings for Mazatlán, Mexico, and Tucson, Ariz.

combination creates the maximum possible thermal potential near the surface for the surge.

It is important to note that because a surge is the result of a low-level thermal gradient, middle-latitude dynamic mechanisms are not contributing factors in developing the surge. On the contrary, a trough in the westerlies would very likely sweep any tropical air out to the north-east over Mexico long before the moisture reached the deserts of Arizona. Therefore, the typical light flow aloft of the summertime is much more favorable for supporting a surge.

There appear to be two types of surges. Type 1 is a relatively deep surge (8,000–12,000 ft) typically generated from the mouth of the gulf by a thick cloud canopy associated with a tropical disturbance. Type 2 is a relatively shallow surge (3,000–5,000 ft) generated by a cloud mass (possibly associated with an easterly wave) moving from the mainland over the gulf itself.

3. SURGE CHARACTERISTICS

Lack of data in this part of the world is a big problem for any synoptic study. A number of characteristics of gulf surges are fairly certain, however.

1. The surge is strongest just above the surface and gradually decreases in intensity with height as would be expected from comparing the Tucson and Mazatlán soundings. A comparison of the two soundings indicates that the maximum depth of an air mass change would be 10,000–13,000 ft. The intensity and depth of surges depend on several factors. The hotter the deserts, the stronger the surge because of the greater contrast in the two air masses. The larger the cloud area, the stronger and deeper the surge. A cloud mass directly associated with a tropical disturbance is very favorable for a strong surge even if the cloud mass only skirts the mouth of the Gulf of California.

2. Cooling always accompanies the surge into Arizona, being first detected in the Yuma area and within 24 hr fanning throughout the remainder of the State in steadily diminishing intensity. Once the surge reaches the deserts, it spreads in all directions but

most strongly up the Colorado River Valley, which would be the path of least resistance as well as the direction of the greatest momentum. As it fans out, it loses its momentum because the original mass is spread over a progressively larger area. Also, solar heating of the deserts causes modification by mixing and warming. Therefore, the forward spread of the boundary, along with the sharp change that is first noted at Yuma, is gradually decreased. The boundary usually spreads no farther northwestward into southern California than the lower desert valleys; the higher elevations from San Bernadino County northward are generally unaffected. Occasionally, when midtropospheric winds are from the southeast, thunderstorm activity generated from one of the deeper surges will be carried far to the north or northwest. The surge normally spreads northward and northeastward through the mountains of Arizona due to its greater depth in this direction of movement. Also, the upper circulation usually favors this direction of movement. However, the surge is usually dissipated by the time it reaches the northern border of the state. Las Vegas, Nev., may feel limited effects under favorable conditions.

3. Usually, the only way to detect changes brought about by the surge in the higher elevations of northern Arizona is through 24-hr changes in temperature, dew point, and possibly pressure. Changes in the weather pattern associated with the surges vary with each situation. With the relatively shallow type 2 surge (3,000–5,000 ft), strong but short-term cooling takes place mainly in the deserts stabilizing the air mass. Thunderstorms will usually be inhibited by this low-level cooling in the deserts and decreased in the mountains. Those thunderstorms that do occur, however, could be heavier due to the added moisture in the atmosphere and to the lower condensation level.

4. With a deep type 1 surge (8,000–12,000 ft), thunderstorms will sharply increase over all of Arizona with possible heavy activity. They will further add to the cooling factor. Recovery of temperatures will then depend on the variation in shower activity but nevertheless will be a slower process.

5. The surge is strongest at its onset, and its push gradually decreases as the heat low in the desert is filled and equilibrium is reached again. With no midlatitude system complicating the situation, this should occur within 24 hr after onset of the surge.

6. The magnitude of the maximum temperature drop over a 24-hr period is usually on the order of 5°C or more in the southwestern deserts and 3°–5°C elsewhere in Arizona. This drop varies, being greater with a stronger surge associated with clouds and showers and less with no accompanying clouds. In all cases, the relative humidity substantially increases at the surface, particularly in the deserts.

4. CASE STUDIES

Of six documented cases of gulf surges, one occurred in 1967, three in 1969, and two in 1970. Only 1969 and 1970 were thoroughly investigated; therefore, there probably were other occurrences in 1967 and 1968. Four of the six surges (and by far the strongest) were type 1, caused by cloud masses associated with tropical disturbances moving across the mouth of the gulf. The other two were type 2, associated with cloud masses over the gulf itself. Case studies of the better documented type 1 cases and one of the type 2 cases are presented below.

Surge of Sept. 1–2, 1970

The Improved TIROS Operational Satellite (ITOS) photograph at 2230 GMT on Sept. 1, 1970 (fig. 3), indicated that the northern edge of a large mass of tropical cloudiness had reached an east-west line across the southern tip of Baja California. At the time of the photograph, tropical

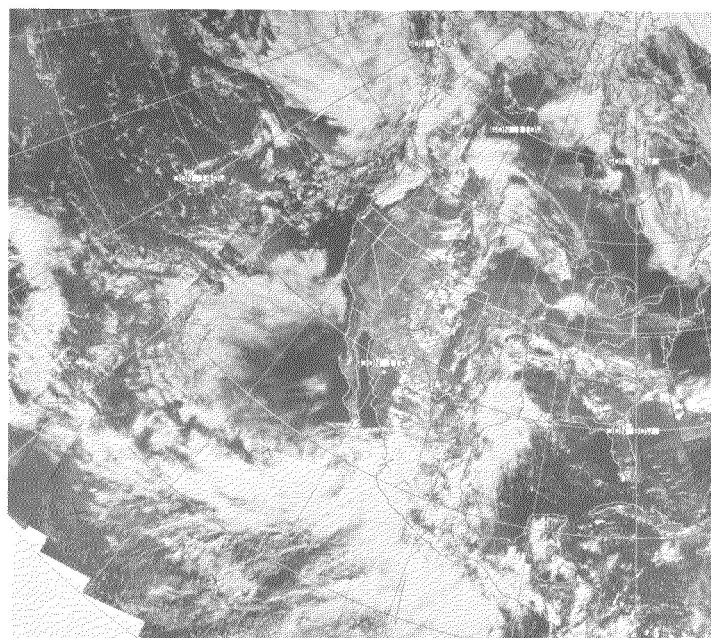


FIGURE 3.—ITOS 1 photograph, pass 2769, at 2130 GMT, Sept. 1, 1970.

TABLE 1.—Hourly surface observations for La Paz, Mexico, on Sept. 1 and 2, 1970

Time (GMT)	Sky condition	Visibility	Pres/T/Td/wind
2100	Missing		080/38/M/3415
2200		Missing	
2300	400/0	15+	M/39/M/1815
0000	800/0	15+	078/33/22/1810
0100	800/0	15	078/32/22/1806

storm Norma was located about 300 mi south of La Paz, Mexico (Denney 1971).

As can be noted from the surface observations at La Paz (table 1), a definite change of air mass occurred between 2100 GMT on September 1 and 0000 GMT on September 2. La Paz's temperature of 39°C at 2300 GMT was exceptionally high since its alltime record maximum temperature is only 3°C higher. The wind shifted from northerly to southerly by 2300 GMT, followed by a temperature drop of 6°C in 1 hr at the hottest time of the day. No observations were available along the Gulf of California until 1300 GMT on September 2. At that time, Puerto Peñasco, Mexico, reported a southeast wind of 15 kt. This wind increased steadily during the day and by 2100 GMT it was blowing from 150° at 30 kt. It gradually diminished after 0000 GMT.

The Yuma, Ariz., sequence on the morning of Sept. 2, 1970 (table 2), indicates a pronounced change in air mass from 1500 to 1600 GMT. This discontinuity line continued to spread into the deserts of southern California and western Arizona with similar changes at Imperial, Blythe, and Needles, Calif.

The 24-hr temperature, pressure, and dew-point temperature change map between September 1 and 2 at

TABLE 2.—Hourly surface observations for Yuma, Ariz., on Sept. 2, 1970

Time (GMT)	Sky condition	Visibility	Pres/T/Td/wind
1400	0	85	040/25/13/0000
1500	0	85	054/30/10/1415 G20
1600	0	30	059/32/23/1617
1700	0	25	061/35/25/1813

TABLE 3.—Hourly surface observations for Blythe and Imperial, Calif., on Sept. 2, 1970

Time (GMT)	Sky condition	Visibility	Pres/T/Td/wind
Blythe, Calif.			
2000	0	40	040/41/02/1813
2100	Missing		034/41/07/1915
2200	1000	40	027/41/16/2313
2300	1200	40	020/41/17/2112
Imperial, Calif.			
2100	0	20	041/41/06/1006
2200	0	30	031/42/18/2504
2300	900	30	024/41/20/0913
2400	0	25	028/40/21/1515

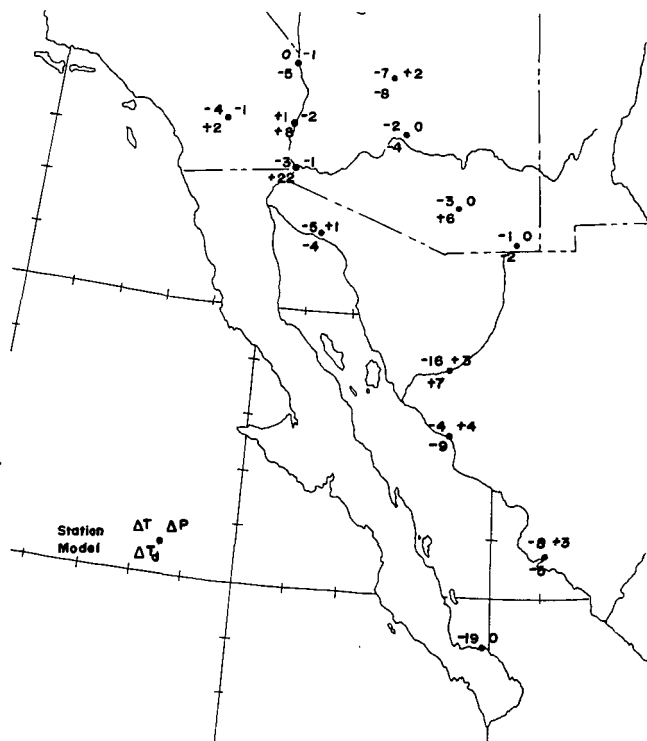


FIGURE 4.—The 24-hr change from 2100 GMT, Sept. 1, 1970, to 2100 GMT, Sept. 2, 1970, in temperature, dew point, and pressure at surface stations in northwestern Mexico, Arizona, and south-eastern California.

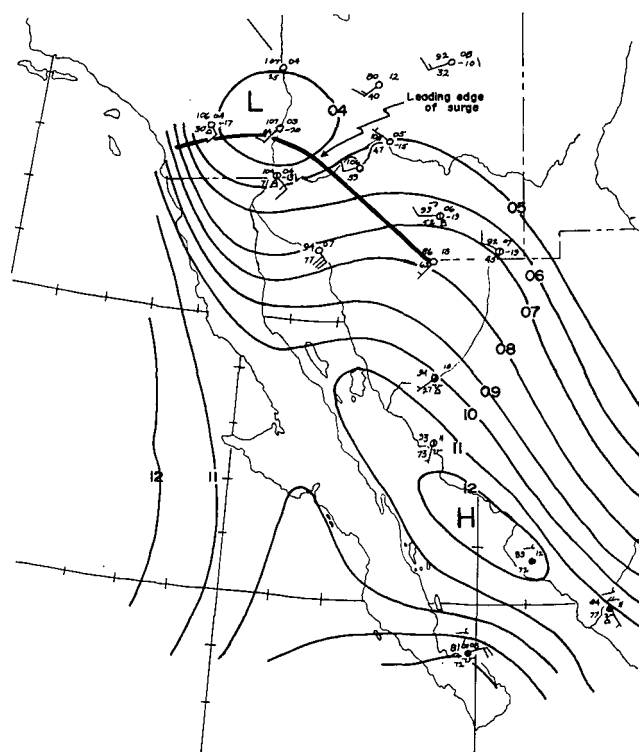


FIGURE 5.—Isobaric analysis for 2100 GMT, Sept. 2, 1970.

2100 GMT (fig. 4) reveals significant temperature drops along the entire west coast of northern Mexico. The largest temperature drops are noted inland since modification by the gulf reduced the change of afternoon air temperatures along the coast on September 1. At 2100 GMT on September 2, the discontinuity line was just south of Blythe and Imperial, Calif., as shown in table 3. Everywhere to the north of the line, temperatures showed very little change. The 7°F (3.9°C) change at Prescott, Ariz., is somewhat misleading because the change in maximum temperature was only 1°F (0.6°C).

The most important 24-hr change occurred in the pressure. Along the entire gulf coast, pressure rose, while at all other stations except Prescott, pressure remained constant or fell 1–3 mb. There was a strong isallobaric difference along a line from Blythe, Calif., to Guaymas, Mexico. At 2100 GMT September 2, a strong (8 mb) pressure difference existed between Blythe and Guaymas (fig. 5). This pressure difference combined with the channeling

effect of the gulf accounts for the persistently strong winds at Puerto Peñasco during the day. Farther to the south, the pressure field was flat along the coast. This supports the lack of any significant surface air movement along the west coast of Mexico south of Guaymas, indicating that the new tropical air mass was of near-uniform density. The one station where the pressure change was negligible was La Paz. However, La Paz, with wind from the east at 20 kt, was most likely under the fringe influence of tropical storm Norma.

Finally, the dew-point change over the 24-hr period should be mentioned. At first glance, the changes along the gulf coast do not seem to fit because they are all significantly negative. However, large bodies of water at this latitude usually reach their maximum temperature during September. Because the gulf is small compared to

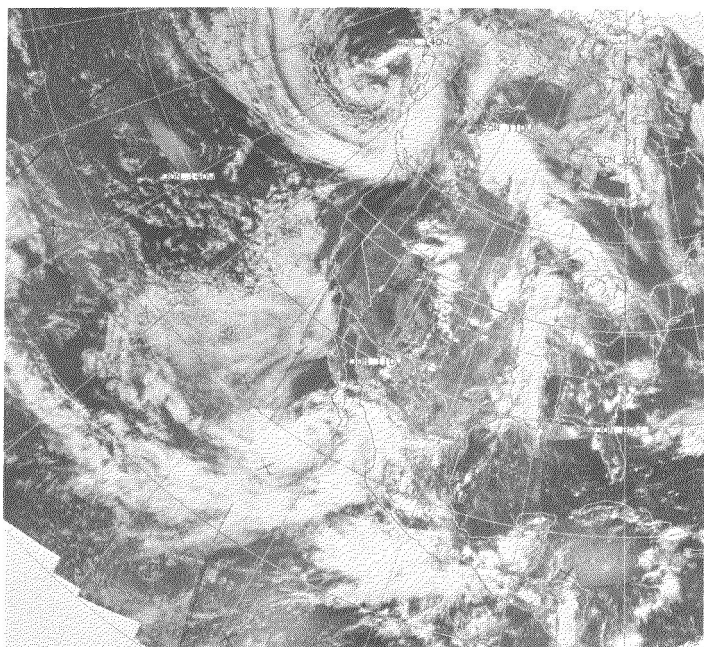


FIGURE 6.—ITOS 1 photograph, pass 2782, at 2130 GMT, Sept. 2, 1970.

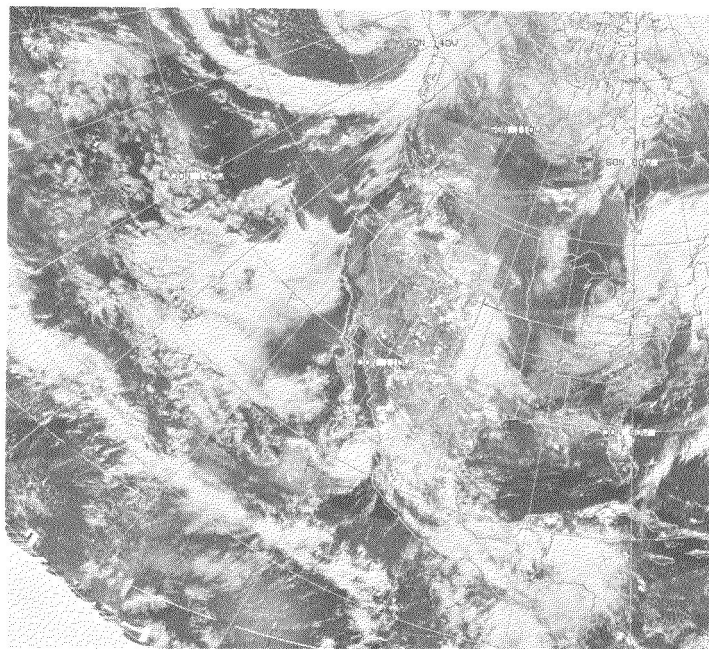


FIGURE 8.—ESSA 9 photograph, pass 2442, at 2039 GMT, Sept. 9, 1969.

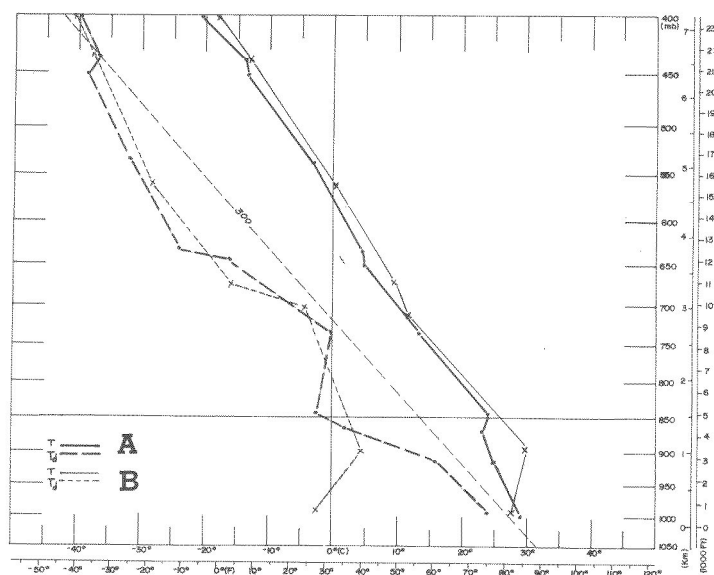


FIGURE 7.—Yuma, Ariz., upper air soundings for 1200 GMT, (A) Sept. 3, 1970, and (B) Sept. 2, 1970.

the Pacific Ocean and is surrounded by a hot, arid land mass, it follows that the gulf's temperature in September should be very high. Dew points in the low 80s at Puerto Peñasco and Guaymas, Mexico, on the 1st indicated this. With the change to an air mass from the Pacific on the 2d, even though it is from a more southerly latitude, dew-point temperatures fell into the mid 70s because of the cooler water of the source region. Inland at Hermosillo, Mexico, where the effects of the gulf are less than they are at coastal locations, the dew point shows a rise of 7°F (3.9°C). At Yuma, where an arid continental air mass was replaced by a tropical maritime air mass, a 22°F (11.2°C) jump in dew point occurred.

The computed time for the surge to advance from La Paz, Mexico, to Yuma, Ariz., was 17 hr, or at a speed of approximately 30 kt. This agrees quite well with the average wind speed during the afternoon of the 2d at Puerto Peñasco.

The ITOS satellite picture for 2239 GMT on September 2 (fig. 6) indicates that the cloud mass continued to move northward, but the leading edge was still south of Arizona, being located across the Gulf of California at 27°N. The tropical storm had moved to a position some 250 mi southwest of La Paz.

Tropical moisture continued to move into Arizona for 3 days as a middle-latitude trough deepened unseasonably far south into the Great Basin. The 1200 GMT radiosonde runs for Yuma on September 2 and 3 (fig. 7) illustrate the extent of infiltration by the tropical air mass. The depth of moist air was about 5,000 ft at 1200 GMT on the 3d with considerable cooling occurring below that level along with a tremendous increase in moisture.

The combination of the tropical air mass and the strong middle-latitude system resulted in one of the heaviest storms ever to hit Arizona, on Labor Day, Sept. 5, 1970 (Zimmerman et al. 1971). New state records were set for 24-hr precipitation in both Utah and Arizona. The Arizona record of 11.40 in. at Workman Creek 1 almost doubled the previous 24-hr record.

Surge of Sept. 10–11, 1969

This case is very similar to the previous one. A tropical disturbance passed just south of the mouth of the Gulf of California on Sept. 9, 1969, as can be seen from the Environmental Survey Satellite (ESSA) 9 photograph at 2039 GMT (fig. 8). Data from Mexico was lacking for this particular situation. However, from teletypewriter se-

TABLE 4.—Hourly surface observations for Yuma, Ariz.; Blythe and Needles, Calif.; and Las Vegas, Nev.; Sept. 10–12, 1969

Time (GMT)	Sky condition	Visibility	Pres/T/Td/wind
Yuma, Ariz.—Sept. 10, 1969			
1300	1100	40	061/31/16/1409
1400	1100	40	074/30/21/1408
1500	1100	25	081/31/26/1520G25
1600	1100	25	088/34/25/1523G28
Blythe, Calif.—Sept. 10, 1969			
1600	900	40	084/35/10/1605
1700	900	40	087/36/21/1715
1800	0	25+	090/38/21/1715G22
Needles, Calif.—Sept. 11, 1969			
0300	1100	15+	058/40/08/1810
0400	0	15+	064/39/13/1810
0500	0	15+	067/38/16/1812
0600	0	15+	073/37/17/1912
Las Vegas, Nev.—Sept. 12, 1969			
1100	0	15+	121/25/02/1706
1200	0	15+	124/26/16/0804
1300	0	35	131/27/19/1908G15
1400	800/0	25	134/27/18/1711G20

quence reports for Yuma, Ariz., on September 10 (table 4), it can be seen that the surge passed that station between 1300 and 1500 GMT, resulting in an abrupt rise in dew point and gusty winds to 32 kt (28 mi/hr) at 1600 GMT. This was approximately 17 hr after the time of the ESSA 9 picture, or the same time interval that was noted in the previous case during which the surge moved from La Paz, Mexico, to Yuma. There was a pronounced surge passage later in the day at Blythe and Needles, Calif. (table 4). On September 12, Las Vegas, Nev., reported a 24°F (14°C) jump in dew point between 1100 and 1200 GMT with an increase in southerly winds thereafter.

The Tucson, Ariz., radiosonde observations for September 10 and 11 (fig. 9) illustrate what happens when the moist air moves off the gulf and is lifted by the desert terrain and heating. The 24-hr cooling is still quite sharp, particularly near the surface, with the moisture increasing to much greater elevations than at Yuma because of mixing.

The tropical disturbance continued to move northwestward to a position about 28°N, 120°W where it dissipated on September 14. The moisture continued to flow into Arizona through September 12, at which time equilibrium had again been attained. The air mass remained quite moist for the next several days with very little surface air movement. This tropical moisture, in conjunction with a subtropical jet stream, triggered some exceptionally heavy convective activity. On September 14, a thunderstorm dropped 3.52 in. of rain in 1 hr on Tempe, Ariz., establishing a new Arizona one-hourly precipitation record. On September 16, another storm set several short period records at the Phoenix Sky Harbor Airport, dropping 1.00 in. of rain in a 10-min period. Temperature

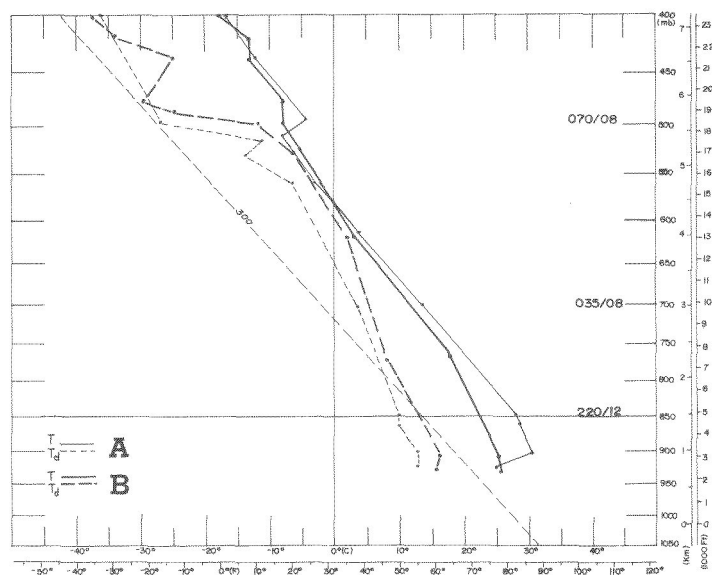


FIGURE 9.—Tucson, Ariz., upper air sounding for 1200 GMT, (A) Sept. 10, 1969, and (B) Sept. 11, 1969.

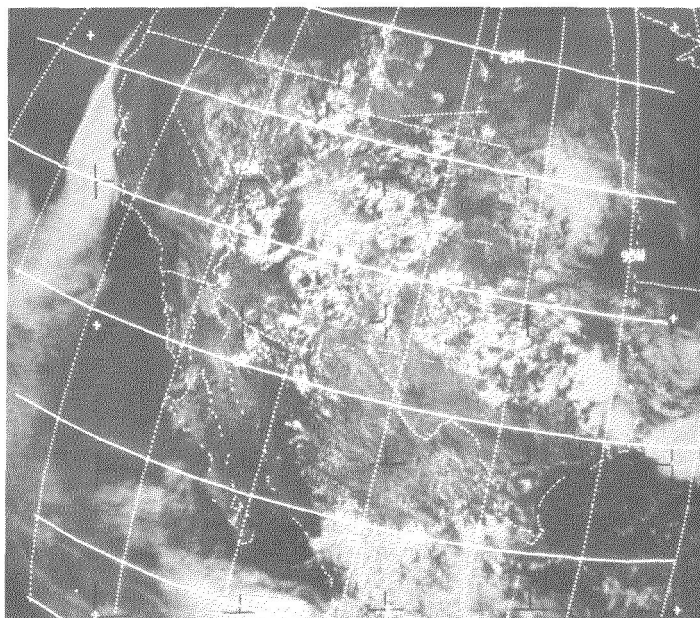


FIGURE 10.—ESSA 9 photograph, pass 2217, at 2100 GMT, Aug. 22, 1969.

drops resulting from the surge varied from about 5°C along the eastern and northern border sections to as much as 10°C in the southwest deserts.

Surge of Aug. 23–24, 1969

This particular case was chosen because of the availability of data from Mexico. By comparing the ESSA 9 satellite photograph taken on August 22 with that taken August 23 (figs. 10, 11), one can see that a tropical disturbance moved across the mouth of the Gulf of California.

The passage of the surge can be followed past each station in table 5 beginning at Guaymas, Mexico, about

TABLE 5.—Hourly surface observations for Guaymas and Puerto Peñasco, Mexico; Yuma, Ariz.; and Imperial, Thermal, and Blythe, Calif.; Aug. 23 and 24, 1969. Rules indicate surge passage.

Time (GMT)	Sky condition	Visibility	Pres/T/Td/wind
Guaymas, Mexico—Aug. 23, 1969			
1600	/ ☉	20	081/32/25/0000
1700	150/ ☉	20	091/33/25/1212
1800	150/ ☉	15	095/33/25/1212
2300	200/ ☉	30	091/33/25/1512
Puerto Peñasco, Mexico—Aug. 23, 1969			
2100	1200	35	041/37/20/2010
2200	1200	35	044/36/20/1010
2300	300	35	040/36/21/2010
Yuma, Ariz.—Aug. 24, 1969			
0200	1400	20	019/41/14/1717
0300	1400	10	033/38/20/1525 G31
0400	1200/0	12	050/36/21/1520 G26
Imperial, Calif.—Aug. 24, 1969			
0400	120- ☉/- ☉	10	034/37/15/1609
0500	/- ☉	10	051/34/21/1015
Thermal, Calif.—Aug. 24, 1969			
0500	120-0	10	034/36/06/2506
0600	0	10	054/36/21/1612
Blythe, Calif.—Aug. 24, 1969			
0500	100 ☉	15+	046/39/14/0810
0600	100 ☉	15+	056/38/16/1312
0700	100 ☉	15+	073/35/19/1218
PRESRR			

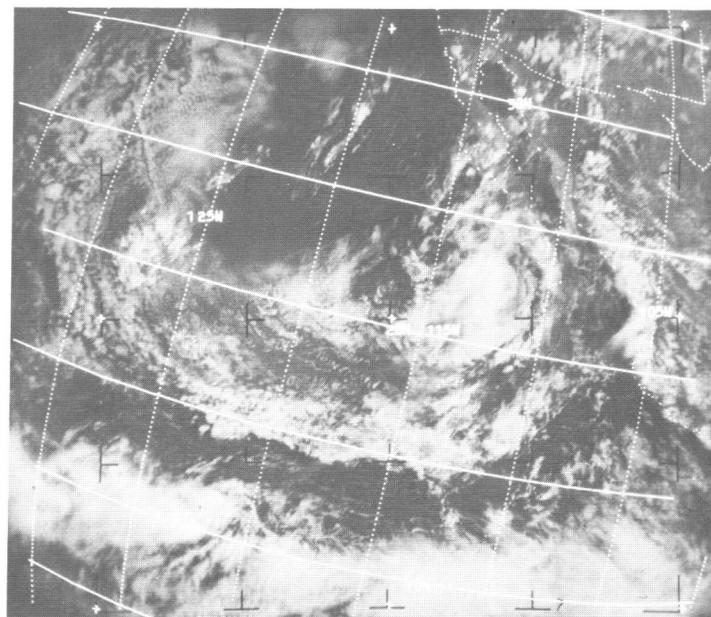


FIGURE 11.—ESSA 9 photograph, pass 2230, at 2154 GMT, Aug. 23, 1969.

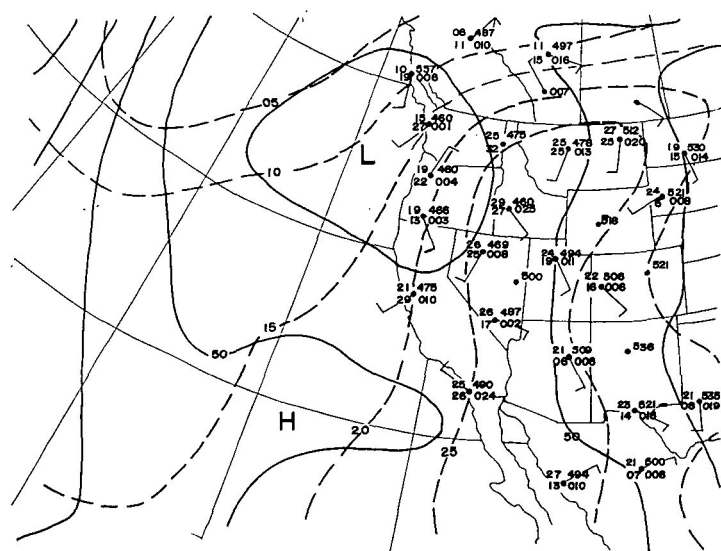


FIGURE 12.—The 850-mb analysis for 1200 GMT, Aug. 23, 1969.

1600 GMT on August 23 and finally passing Blythe, Calif., some 14 hr later. Similar changes are noted at each station—south to southeast winds, sudden jump in dew-point temperatures at inland locations, a leveling off of temperatures during the daytime (Guaymas temperature did not rise further after the surge passage), and a rise in pressure.

In this case, a disorganized line of clouds followed the surge up the gulf as can be noted from the satellite picture taken on August 23 (fig. 11). Also, from the surface report, clouds generally increased following the passage.

The 850-mb charts for 1200 GMT on September 23 and 0000 GMT on September 24 (figs. 12, 13) point out very

clearly the change in air mass at this level after the surge passage. The Guaymas, Mexico, report indicated a veering of winds from a 10-kt northeast wind to a 13-kt southeast wind, a height rise of 30 m, a temperature drop of 6°C, and a decrease in dew-point spread from 13° to 8°C. The temperature drop and height rise are very unusual from morning to evening in this area during the summer months because of the strong diurnal changes. This change at the 850-mb level agrees very well with the time of surge passage (1600 GMT at Guaymas) and also with the lack of any further warming during the day at that station.

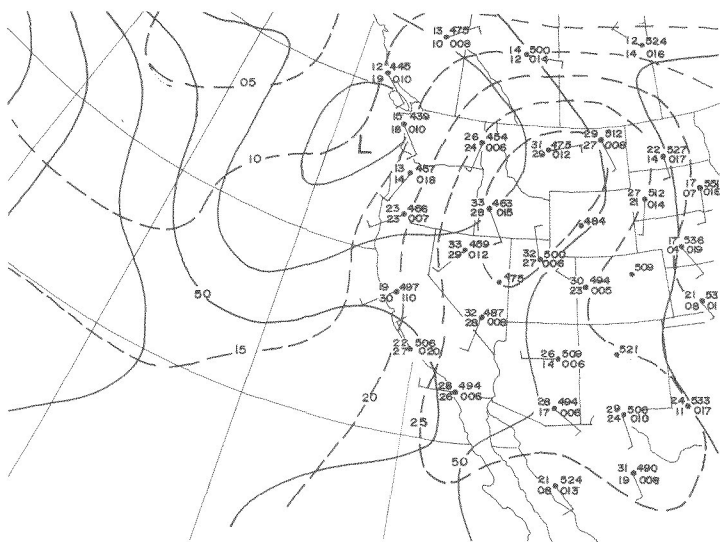


FIGURE 13.—The 850-mb analysis for 0000 GMT, Aug. 24, 1969.

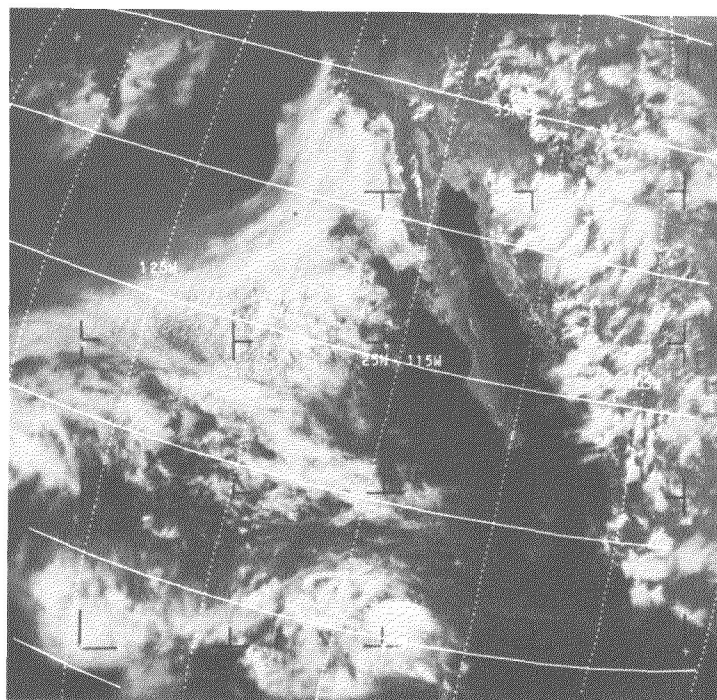


FIGURE 14.—ESSA 5 photograph, pass 1349, at 2246 GMT, Aug. 4, 1967.

Surge of Aug. 5, 1969

This case is one of two documented incidences of a surge initiated between the mouth and the northern end of the Gulf of California. The ESSA 5 photograph taken Aug. 4, 1967, at 2246 GMT (fig. 14) shows the gulf completely clear with much convective activity over Mexico's mountains. On the ESSA 5 photographs taken August 5 at 2133 GMT (fig. 15), a large area of cloudiness is noted over the northern third of the gulf. Although part of this

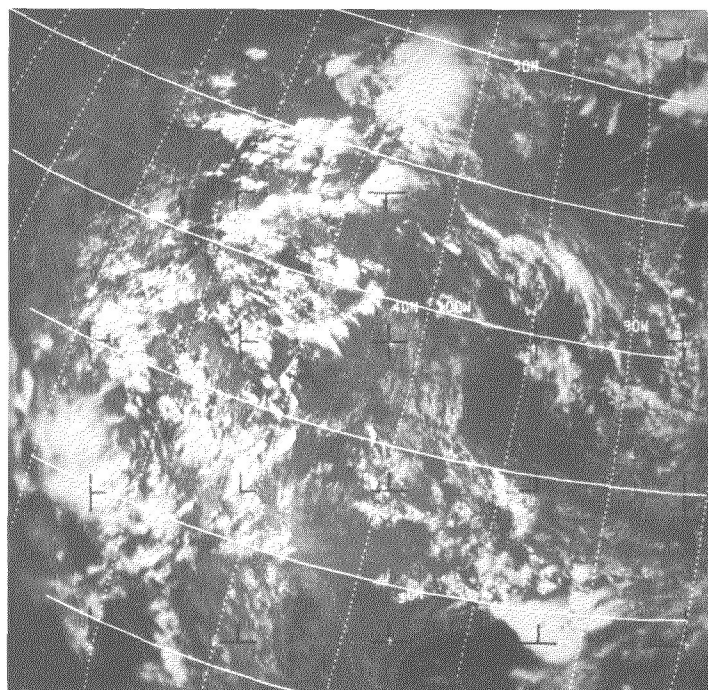


FIGURE 15.—ESSA 5 photograph, pass 1361, at 2133 GMT, Aug. 5, 1967.

TABLE 6.—Hourly surface observations for Yuma, Ariz., Aug. 5, 1967

Time (GMT)	Sky condition	Visibility	Pres/T/Td/wind
1800	/- ☉	30	112/37/17/1718
1900	-X1200 U ☉	1½BD	117/37/18/1412G26
2000	/- ☉	10	112/36/18/1720G25

cloud is cirrus, two large groups of convective clouds over the water are apparent.

Yuma, Ariz., surface reports for August 5 (table 6) indicate that a surge passed between 1800 and 1900 GMT accompanied by gusty winds, blowing dust, and a slight rise in dew point and pressure. Although skies were clear, with the exception of cirrus clouds throughout the afternoon, the temperature of 37°C at 1900 GMT was never again reached, indicating a change in air mass. Also, the afternoon temperatures were 3–4°C cooler than on the previous day at the same time. This cooling spread northward up the Colorado River Valley and resulted in a drop of the maximum temperatures at both Blythe and Needles, Calif., of 7°C on August 6.

This type of surge is neither as strong nor as long lasting as the surge from the mouth of the gulf, where a much deeper layer of tropical air is available to be channeled into the deserts; but as shown, it does bring with it a definite change of air mass. The generating cloud mass was most likely associated with a weak easterly wave that

progressed westward across northwest Mexico. The northern edge of the cloud area resulted in thunderstorm activity at Yuma late in the evening of August 5. It was, however, some 10 hr after the surge passage, and obviously they were unrelated.

5. SUMMARY

One aspect of the influence of the Gulf of California on summertime weather over the desert Southwest has been presented. The channeling of a tropical air mass into Arizona can result in very significant rainfall and frequently causes a sharp change of air mass.

The concept of the gulf surge may also help to explain the hard-to-accept statement made quite often that circulation around a tropical disturbance several hundred miles out in the Pacific results in an increase of tropical moisture over Southern California and Arizona (Green 1963, Green and Sellers 1964). Little effort was made to determine the actual dynamic mechanisms involved in initiating a surge because of the lack of data for each case. With the infrared capabilities of present day satellites, new insight into the processes that generate the surge may be possible.

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